Dynamic oxygen mapping in tumors by ^{19}F MRI

Steven Baete

Supervisor(s): Yves De Deene

Tumour hypoxia is well known to reduce cancer treatment efficacy. Hypoxic tumour cells, which have decreased oxygen levels (pO_2), are more resistant to radiotherapy and chemotherapy. Identification of hypoxic tumour tissue may improve cancer treatment. The oxygen levels in tissue can be imaged in a non-invasive way by ^{19}F MRI oximetry. That is, one of the parameters which can be measured quantitatively with magnetic resonance imaging (MRI), the spin-lattice relaxation rate R_1 ($R_1 = 1 / T_1$) of perfluorocarbons, is sensitive to changes in oxygen tension pO_2 [1]. This technique has been used in animal studies to dynamically image tumour oxygenation (e.g. [1]). However, validation of pO_2-measurements in vivo is difficult. In this study a reproducible phantom, simulating well perfused oxygen consuming tissue, is presented. Furthermore, computer simulations are used to study the impact of perfluorocarbon distribution and concentration in tissue on ^{19}F MRI oximetry.

I. Phantom

A phantom (figure 1)[2] was used to simulate and image acute and perfusion-related hypoxia spatially and temporally. This phantom can be employed to simulate oxygen consumption by somatic cells in vivo and for validating computational biophysical models of hypoxia, as measured with ^{19}F MRI oximetry.

II. Simulation

A Krogh tissue model is implemented. This model, in which a tissue cylinder surrounds a capillary, incorporates the presence of perfluorocarbons in blood and tissue. Mean oxygen tension pO_2 in the simulation volume is compared with pO_2 as it would be measured by ^{19}F MRI oximetry, pO_2^{FNMR}.

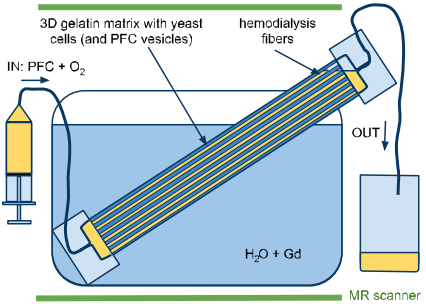

Figure 1. Schematic of a phantom for the validation of ^{19}F MRI-oximetry methods. The phantom consists of a hemodialysis filter placed in an MR-scanner and an automated syringe pump. The outer compartment of the filter is filled with a gelatin matrix containing viable yeast cells simulating oxygen consuming tissue. Also perfluorocarbon emulsions can be added to the gelatin matrix.

Simulation results indicate that the agreement between measured pO_2^{FNMR} and actual pO_2 is influenced by vascular density, perfluorocarbon distribution and perfluorocarbon concentration. Only homogeneous perfluorocarbon distribution in tissue guarantees small deviations of pO_2^{FNMR} from pO_2. Hence, the perfluorocarbon distribution and concentration have a serious impact on the accuracy of ^{19}F MRI oximetry.

Acknowledgments

This research is supported by grants #01J13507 and #01D21208 from the BOF-Ghent University. The author is a PhD Fellow of the Research Foundation - Flanders (FWO).

References

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S. Baete is with the Dept. for Radiation Oncology and Experimental Cancer Research, Ghent University (UGent), Gent, Belgium. E-mail: Steven.Baete@UGent.be .